LEHIGH
nano TECHNOLOGY

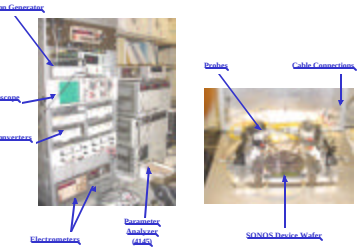
Lehigh Integrated Nano-Characterization User Facilities

Linking to the University of Pennsylvania

Contact:
Gene A.Lucadamo
Industrial Liaison
Materials Research Center
Lehigh University
Bethlehem, PA 18015-3194
610-758-4855
eal7@lehigh.edu
http://www.lehigh.edu/~inmatsc

Electronics	Mechanical	Structural	Chemical	Education

Nanoelectronics Laboratory Measurements



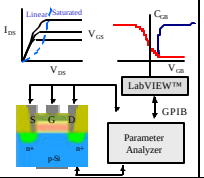
Electrical Parameter Measurements

Measurement (HP 4145)
- in Current (I_{DS}) vs. Gate Voltage (V_{GS})
- n Current (I_{DS}) vs. Drain Voltage (V_{DS})

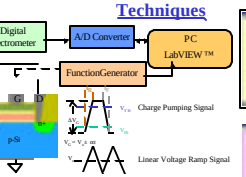
Measurement (HP 4192)
- acitance (C_{GB}) vs. Gate Voltage (V_{GB})

ved Results (SPICE Parameters)
- Transconductance (G_M)
- Threshold Voltage (V_{TH})
- Flat Band Voltage (V_{FB})
- Doping Concentration (N_A)
- Fermi Potential (Φ_F)
- Transistor Gain (β_0)
- Surface Roughness Coefficient (θ_S)
- Series Resistance (R_S)
- Mobility (μ_n, μ_p)
- Oxide Thickness (T_{ox})
- Flat Band Voltage (V_{FB})

LabVIEW™
- Create graphically oriented PC programs for automated control of laboratory equipment.
- Data displayed on a PC screen and stored in text files.



Charge Pumping and Linear Voltage Ramp Techniques

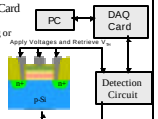


ge Pumping Technique:
ermine interface and near interface traps densities
y the device reliability to endurance stress of thin oxides
r voltage ramp (LVR) or Split -C-V technique

aracterize the mobile ions in the oxide layer when performed a t elevated temperatures.
act independently inversion charge to determine the effectiv e device mobility
act thickness of multi-layer thin gate dielectric devices, such as NVSM devices.

aracterization of Nonvolatile Semiconductor Memories

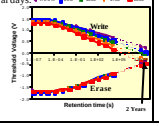
ble Test Setup - National Instruments DAQ Card
- range of applied voltages and timing.
- am device using either Fowler -Nordheim Tunneling or ectron Injection.
- /IEW™ interface for data display/storage.



Procedure:
- Set temperature for test.
- Write or Erase device.
- Detection circuit extracts Threshold Voltage (V_{TH}) at times ranging from 3 hours to several days.

y Device Under Test

ts:
mine time limit of charge retention.
charge retention at elevated temperatures ranging 2 to 400 C.
charge retention after millions of Erase/Write cycles vice endurance (stressing).
act trap densities and energies in Nitride charge
e films using retention data at varied temperatures.
programming efficiency at varied voltages.

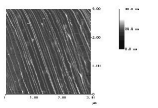


Nano-characterization in the Nano-Mechanical Behavior Laboratory

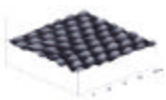
Scanning Probe Microscopy
- Digital Instruments (DI)Nanoscope III
- surface imaging in air or in solution
- contact (AFM) or Tapping Mode
- electrochemical stages

Contact and tapping modes, and electrochemical stages for control of reactions *in-situ*. Imaging may be performed in air or under desired solution. A Hysitron Triboscope Nanoindentation attachment allows surface imaging and indentation, and measurement of elastic and plastic properties, with indentation of 20 nm. Forces on order of µN to mN may be applied. Temperature control up to 150°C.

AFM Imaging of Nanostructures

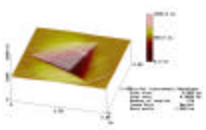


AFM image of PTFE lines drawn out by the friction transfer technique onto a glass slide.

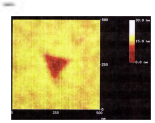


STM image of self-assembled Au nanoparticles on highly ordered pyrolytic graphite

Nano Indentation



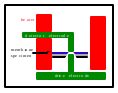
To analyze plastic deformation mechanisms in nanocrystalline materials at very low-load and identify microstructural influences during shallow (only 3-30 nm) indentation
Results are applicable to interpretation of nanoindentation tests and to nano-asperity contact of surfaces in nanomechanical devices.



Nano Indentation of a Platinum thin film with the Hysitron Triboscope
(150 nm "diameter", 14 nm depth)

Thin Film Creep Studies

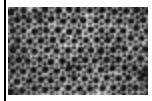
Analyze, model, and control stress relaxation / dimensional stability for nm-scale metal films by applying a new resonance based measurement technique with unprecedented sensitivity.



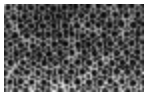
Thin Film Creep Measurement by Membrane Resonance. Operates up to 500 °C, with film thickness of 20-100 nm, stress resolution typically < 1 MPa

Transmission Electron Microscopy

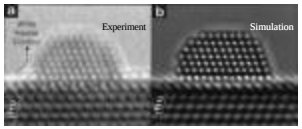
JEOL 2010F
State-of-the-art 200kV microscope with a field-emission gun. It is equipped with energy dispersivespectroscopy (EDS) and an energy filter for electron energy-loss spectroscopy (EELS) and energy filtering of images and diffraction patterns. .

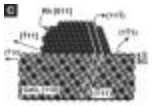


Size selected sintering of a bimodal array of self-organized gold nanoparticles observed in the JEOL 2010F



Lattice Imaging of Nanoparticles



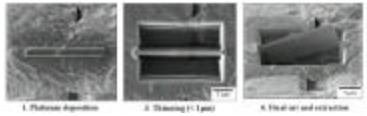


A rhodium catalyst nanoparticle supported on cerium oxide:
(a) experimental HREM image
(b) simulated HREM image
(c) structural model

Focused Ion Beam Thinning

FEI Strata DB 235

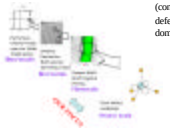
This Dual-Beam FIB is a combination of a scanning electron microscope (SEM) with a focused ion beam system (FIB). It is used for preparing TEM samples from specific localized areas and the nano-patterning of substrates.



Stages of preparation of piezoelectric ceramic TEM-foil

Optical Spectroscopy and Luminescence Microscopy of Nano-Structures

We combine the spatial resolution of a confocal microscope and n ear field optical microscope with the high spectral resolution and selectivity offered by combined excitation-emission spectroscopy. This allows correlation of atomic scale defects with optical properties observed on the nanoscale.



Domains in a confocal luminescence microscope (contrast is obtained through changes in the atomistic defect structure which also determine mobility, shape of the domains and the voltage required for domain switching)

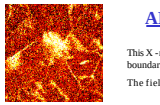
Example:
Ferroelectric domain engineering

Analytical Electron Microscopy

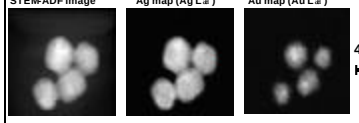
Vacuum Generators HB 603 Scanning Transmission Electron Microscope.

This unique dedicated STEM operates up to 300kV. It is equipped with two EDS systems: one with a standard S(LI) detector and one with an intrinsic Ge detector. Configured with an optimum geometry and large solid angles of collection. This makes our instrument the world leader for high-resolution EDS and EELS analysis.

AEM of Nanostructures



This X-ray map shows Yttrium segregation to grain boundaries in a Y-doped ZrO_2 ceramic.
The field of view is 300 x 300 nm².



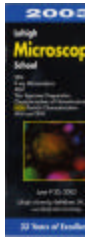
STEM-XEDS elemental maps from Au-Ag core-shell nanoparticles

Surface Chemical Analysis- Angle Resolved XPS Scienta ESCA-300

A unique high resolution, high sensitivity instrument for analysis of the nano chemistry of surfaces. The Scienta has a rotating anode and monochromatized electron gun with a low energy electron diffraction/residual gas analyzer. It operates in the range -175 C to > 600 °C, UHV to one atmosphere.

Lehigh Microscopy School

- World renowned set of short courses in electron microscopy and related techniques.
- Over 5000 scientists, engineers and technicians from universities, industrial research labs and national labs trained since 1970.
- U.S. experts educate participants in scanning, transmission, analytical and other microscopies and spectroscopies .
- Of particular relevance to nanoscale science are unique courses on.
  - **Characterization of Nanostructures**
  - **Atomic Force and Scanning Probe Microscopy (AFM/SPM)**
  - **Analytical Electron Microscopy (AEM)**



Nanoelectronics Educational Programs

Electron-beam Writing

Educational programs stress both theory and application.

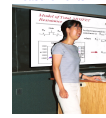
STRONG FOUNDATION
Community outreach in nanoelectronic short courses is an important program - component.

Processing

Industrial Users form a strong partnership in a university - industry affiliates program.

WIDE STUDENT BASE
Advanced processing and measurement facilities provide a rich hands-on environment.

EXTENSIVE FACILITIES



Device Measurements

Theory

MatPAC
Materials
Pennsylvania Coalition

Lehigh Universi
U of Pennsylva
Drexel Universit
Penn State U
U Pittsburgh
Carnegie Mello

- Internet2 videoconferencing for shared courses and research collaboration
- Shared research facilities and instrumentation between PA universities
- *Smartboard* & Web-based course materials for shared exchange of knowledge

Managing the Impact of Nanotechnology on Society and the Environment

Lehigh maintains the nation's 3rd oldest Science, Technology, & Society Program - a year tradition of collaborative interdisciplinary research in the e social, ethical, an political implications of scientific research and technological innovation

Science, Nanotechnology, & Society Programs are needed :
- To sensitize people as early as possible to the anticipated, and profound social consequences of nanotechnology, especially in the area of molecu lar biotechnology, defense, and robotics
- To encourage cross-disciplinary thinking to accomplish constructive, rather tha destructive, nanotechnology applications
- To consider the social and environmental consequences of nanotechnology as p of the R & D process
- To promote the positive impacts of nanotechnology on the environment (eg. improved sensing techniques and processes for removal of the sma llest contaminants in water, soil and air)
- To debunk misinformation and disseminate accurate information on nanotechnology

In-situ Molecular Characterization of Nano-Oxides Under Different Temperature, Pressure and Gaseous/Liquid Environments

Optical Molecular Spectroscopies

T = -200 to 1500 °C

- Laser Raman Spectroscopy (Structure of Metal Oxides, as small as 0.4 nm)
- Infra Red Spectroscopy (Complementary to Raman)
- UV-VIS Spectroscopy (Oxidation States of Metal Oxides, as small as 0.4 nm)